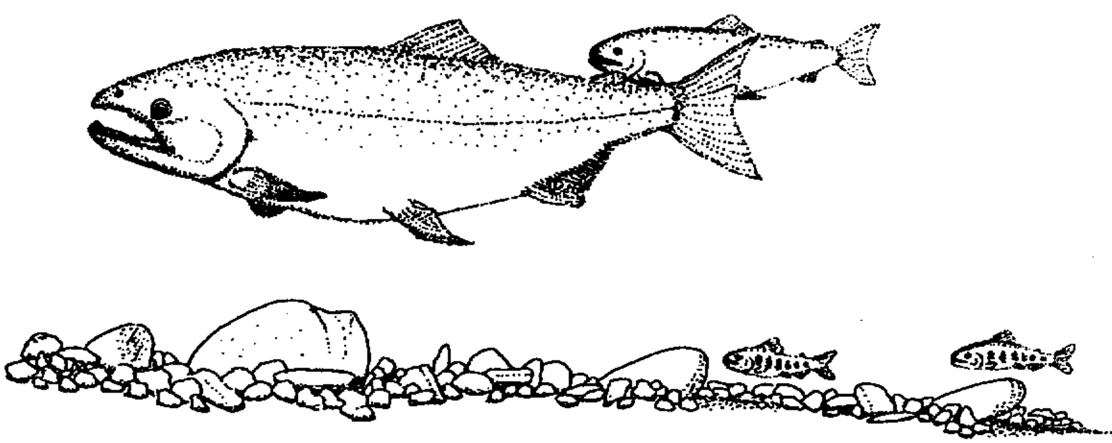
U.S. FISH AND WILDLIFE SERVICE

INSTREAM FLOW RECOMMENDATIONS FOR DUNGENESS-QUILCENE AREA SALMON AND STEELHEAD STREAMS



WESTERN WASHINGTON FISHERY RESOURCE OFFICE

OLYMPIA, WASHINGTON

SEPTEMBER 1993

INSTREAM FLOW RECOMMENDATIONS FOR THE DUNGENESS-QUILCENE AREA SALMON AND STEELHEAD STREAMS

PREPARED FOR THE DUNGENESS-QUILCENE REGIONAL PLANNING GROUP

by

Joseph M. Hiss

U.S. Fish and Wildlife Service
Western Washington Fishery Resource Office
Olympia, Washington

September 3, 1993

ABSTRACT

Salmon and steelhead instream flow recommendations were developed for 15 streams of Jefferson and Clallam Counties in Washington State. Recommendations were based on the Toe Width Method. Stream width was measured across spawning habitat between bank toes and entered into univariate linear regression models previously developed by the U.S. Geological Survey from other Washington streams to predict spawning and rearing flows preferred by salmon and steelhead.

The result is a set of preferred instream flows for all salmon and steelhead streams (for which the toe width method could be applied) in the Dungeness-Quilcene Regional Water Resource Planning Area (all streams entering the Strait of Juan de Fuca or Hood Canal from Siebert Creek to the Big Quilcene River). Comparison of recommended flows to hydrologic records suggests that, in many study streams, further water appropriation would reduce fish habitat except during high flow events. However, some streams appeared more sensitive than others to further withdrawal, based on the number of months during which observed flows were likely to be less than recommended flows. The least sensitive were some of the streams whose flow was supplemented by diversion from the Dungeness River.

These flow recommendations help to close the information gap left by previous studies conducted by the Washington Departments of Wildlife and Fisheries and the U.S. Fish and Wildlife Service for other streams of the area. These recommendations will contribute to the basis of water allocation negotiations of the Dungeness-Quilcene Regional Planning Group, created by the Washington Department of Ecology to resolve long-standing water use controversies among agricultural, municipal, industrial, and instream resource interests.

PROJECT COOPERATORS

Individuals from the following agencies cooperated with the U.S. Fish and Wildlife Service in designing and implementing this study and interpreting the results:

Jamestown S'Klallam Tribe	Mike Reed
Port Gamble S'Klallam Tribe	Peter Bahls
Point-No-Point Treaty Council	Carol Bernthal
U.S. Forest Service	Mike Donald
U.S. Geological Survey	Tom Higgins Norm Dion Charles H. Swift III (ret.)
National Marine Fisheries Service	Brian Winter, Ph.D.
Washington Department of Ecology	Brad Caldwell
Washington Department of Fisheries	Ken Bates Randy Johnson
Washington Department of Wildlife	Hal Beecher, Ph.D. Tim Rymer

This work was supported by the Jamestown S'Klallam Tribe of Sequim, Washington, through a Cooperative Agreement with the U.S. Fish and Wildlife Service, Region One, Portland, Oregon.

Copies are available from:

U.S. Fish and Wildlife Service
Western Washington Fishery Resource Office
2625 Parkmont Lane SW, Building A
Olympia, Washington 98502-5799

DEFINITIONS

Discharge -- Rate of flow, in cubic feet per second (cfs).

Dungeness-Quilcene Project Area -- The watersheds of all streams entering salt water from the Big Quilcene River to Siebert Creek.

Hydrologic base flow -- That portion of stream flow not originating directly from storm runoff.

Maximum spawning discharge -- discharge at which depths and velocities required for spawning occur over the greatest area of streambed in a study reach (Swift 1979 p.11) (varies among the salmonid species).

Preferred rearing discharge -- discharge that provides optimum wetted area of streambed, taken as the point of greatest curvature in the wetted perimeter-discharge relationship (Swift 1979 p.11) (same for all salmon species; differs slightly for steelhead).

Reach -- length of stream channel, usually 1 to 1 1/2 times the width of the channel, extending upstream from a riffle into a pool (Swift 1979 p.11). In practice, the transition between the laminar flow typical of a pool and the turbulent flow typical of a riffle. This roughly coincides with typical salmon and steelhead spawning habitat.

Regulatory base flow -- A water right for the instream resources (fish, wildlife, recreation, esthetics, navigation, stock watering, and water quality), based on biological and hydrologic criteria, and dedicated to instream use only. Base flow is expressed as a minimum instream flow that is used to condition all future water rights. Base flow has a priority date set when the instream flow rule was adopted into Washington State regulations, and only applies to water rights granted after that time.

Segment -- that part of a stream to which an instream flow recommendation applies, based on the gradient, tributary location, and other factors described in "Methods" section of this report.

Streambed -- part of channel usually not occupied by perennial terrestrial plants, but including gravel bars, and lying between the toe of each bank (Swift 1979 p. 11).

Study area -- The Dungeness-Quilcene Project Area excluding the Dungeness River watershed.

Transect -- A line across the stream perpendicular to the fastest current.

Toe of bank -- The point where the streambed (defined above) and one bank join (Swift 1979 p.26); if the channel has a distinctive toe at each bank, the lower toe is used for reference in measurements. See "Methods" section for further details.

Toe width (also known as "**Toe-of-bank width**") -- Stream width at toe of bank or average of the widths of four transects at a study reach, measured horizontally from the toe of the bank (Swift 1979 pp. 11,26).

Wetted perimeter -- distance across wetted streambed, following the curvature of the bottom (Swift 1979 p.22).

INSTREAM FLOW RECOMMENDATIONS FOR DUNGENESS-QUILCENE AREA SALMON AND STEELHEAD STREAMS

INTRODUCTION

Knowledge of instream flows associated with fishery resources is required to support water resource planning under the Dungeness-Quilcene Process sponsored by the Washington Department of Ecology (WDE)(Dungeness-Quilcene Regional Planning Group 1993). Fish flow requirements for individual streams is essential to rationally allocate water use among fishery needs, irrigation, domestic supply, and industry. Instream flow needs may also aid in planning and regulating land use and urban growth, which can affect stream flows by changing the pattern of surface runoff and the contribution of groundwater to streamflow when surface runoff is absent.

The Washington Department of Game (now Washington Department of Wildlife (WDW)) developed instream flow recommendations for steelhead spawning and rearing for many Dungeness-Quilcene Project Area streams in the late 1970's based on toe width measurements (Beecher 1980a,b; Table 1). The Washington Department of Fisheries (WDF) used these measurements to calculate salmon flows for a few of the larger Project Area streams (WDF unpub. notes; Table 1). These recommendations were not adopted as regulatory base flows because the basins lacked basin plans required for establishing instream flows by regulation (Brad Caldwell, WDE, pers. comm.). Since 1986, controversy over criteria for protection of instream resources (WDF *et al.* 1987) has precluded any basin plans anywhere for adopting instream flows by regulation. This has led to the present alternative strategy of negotiated water use under the "Chelan Forum" process, which established the Dungeness-Quilcene Regional Planning Group (RPG).

The RPG first sought fish flow recommendations for the Dungeness River, the largest river in the Project Area, by reconvening the Dungeness Instream Flow Technical Team. The Dungeness Team recommended monthly flows (Hiss 1993) based on interpretation of previous work (Hiss and Wampler 1991). The RPG then called for compilation and development of flow recommendations for the remaining salmon and steelhead streams of the Project Area. The Jamestown S'Klallam Tribe, acting as the coordinating entity of the RPG, and financially supported by WDE, contracted the U.S. Fish and Wildlife Service (FWS) to develop instream flow recommendations for all remaining salmon and steelhead streams of the Project Area.

Objectives

The objectives of this study were to:

(1) compile all previous instream flow recommendations for the Project Area outside the Dungeness River system, and

(2) conduct measurements leading to instream flow recommendations for salmon and steelhead streams for which no flows have been previously recommended.

STUDY AREA

The Project Area contains several hundred miles of permanent streams supporting anadromous fish (Table 2). Instream flow recommendations have been made for about 92 percent of the Area, based on stream width measurements taken at some point near the foot of the various watersheds (Beecher 1980a,b), or, in the case of the Dungeness, based on the Instream Flow Incremental Method (Hiss and Wampler 1991). The WDF Stream Catalog (Williams *et al.* 1975) indicates approximately 13 additional unmeasured streams probably supporting salmon or steelhead. Anadromous fish might also use Johnson Creek and Stream 17.0284 (Mike Reed, Jamestown S'Klallam Tribe, pers. comm.), Ludlow Creek and East Squamish Creek (Unnumbered stream entering Squamish Harbor at Range 1 East, Township 28 North, Section 33) (Peter Bahls, Port Gamble S'Klallam Tribe, pers. comm.). In addition, sub-watersheds of East Fork Chimacum, West Fork Chimacum, Howe, Leland, Ripley, and East Fork Tarboo Creeks are large enough to be of interest as separate water resources (Bahls, pers. comm.).

Only 15 of the unmeasured streams in Table 2 have perennial flow at a point accessible from a public road, and had one or more reaches reasonably suitable for toe width measurements under criteria described in the "Methods" section below (Table 3). Streams that are intermittent or lacking in riffle-pool transitions are not suitable for toe width measurement. Figures 1-8 illustrate the range of bank and bed characteristics I considered suitable for study reaches.

Flow recommendations derived from suitable reaches represent larger stream segments equally likely to support salmon or steelhead spawning (Table 4), based on similarity of gradient and location relative to tributaries.

The identity and spawning time of salmon and steelhead stocks in many streams appears in the Salmon and Steelhead Stock Inventory (SASSI)(WDF *et al.* 1993). However, anadromous fish use many smaller streams not specified in SASSI (M. Reed, P. Bahls, and Carol Bernthal, Point-No-Point Treaty Council, pers. comms.). Table 5 combines data from these sources to show the presumed stock identity and spawning season of salmon and steelhead using all Project (or Planning) Area streams.

The study area consists of all Project Area streams outside the Dungeness watershed. These streams can be grouped according to predominant habitat issues in the watershed.

- <u>Irrigation diversion</u>. Farmers pump irrigation water from several study area streams for hay and other crops. Irrigation withdrawal on both the east and west forks of Chimacum Creek visibly reduces instream flow during the summer (Roger Short, pers. comm.).

- <u>Urbanization</u>. Some study area streams flow through watersheds undergoing rapid conversion from timber to residential use. Urbanization increases the amount of impervious surfaces, which tend to intensify storm runoff and diminish the groundwater recharge that would otherwise sustain summer flows. Urbanization may also reduce instream flow by increased consumptive use of surface water or groundwater. Conversion is proceeding most rapidly in the Shine, East Squamish, and Ludlow Creek watersheds (Bahls, pers. comm.). However, all study area streams can be expected to suffer some degree of urbanization in the coming decades.

- <u>Irrigation tailwater</u>. Most of the small independent streams of the Dungeness area receive substantial flow from irrigation water diverted from the Dungeness River. These include Meadowbrook, Cassalery, Gierin, Bell, and Johnson Creeks (U.S. Department of Agriculture 1991). Flow recommendations for these streams must be balanced against instream flow needs for the Dungeness River as developed by Hiss (1993).

METHODS

Field Measurements

Maximum spawning flow and preferred rearing flow were derived from measurements of stream width at the bank toe for all previously unmeasured stream segments (Tables 3,4) considered suitable for measurement.

Detailed field methods for toe width measurement did not appear in any available source. Consequently, the following protocol was developed for the study area, based on interpretation of Swift (1976,1979) by Brad Caldwell of WDE; Dr. Hal Beecher of WDW; and Ken Bates of WDF (pers. comms.).

Step One: Define Stream Segment

Define the stream segment in terms of location relative to tributaries, gradient, tidewater, irrigation withdrawal and inflow, and predominant bottom type, using the following criteria:

- A segment should be relatively uniform throughout, with consistent repetition of salmonid microhabitats (Beecher, pers. comm.).

- Segment should be below permanent tributaries, unless purposely located to measure a certain tributary.

- Segment should be above tidal influence.

- Segment should be entirely above or below known diversions.

- Segment may be below irrigation tailwaters, if the purpose is to measure the habitat influenced by tailwater flow.

- Segment should have overall gradient suitable for salmonid spawning.

- A segment should be larger than individual riffles and pools (Beecher, pers. comm.).

Step Two: Select Study Reaches

Select one to four study reach(es) for each segment to meet the following criteria:

- Channel shape should not be influenced by embankments, culverts or riprap (Bates, pers. comm.).

- At least one bank should consist primarily of alluvial material, and not entirely of reed canary grass or tree roots (Bates, pers. comm.).

- Channel should be reasonably stable, that is, not shaped by a recent local streambank failure (Caldwell, pers. comm.).

- Hydraulic control of the reach should consist predominantly of alluvial material, not woody debris, bedrock, or non-native boulders (Bates, pers. comm.).

Step Three: Place Transects

- Normally, one transect should be measured on each of the first four suitable reaches encountered upon entering the study segment (Beecher, pers. comm.).

- Each transect should be perpendicular to the flow at the fastest-flowing point across the channel.

- Place transects to avoid local variation in toe width within the reach due to hydraulic effects of:

  - bedrock,

  - undercut roots of standing trees or their associated seasonal silt bars (Bates, pers. comm.),

  - partially or totally submerged woody debris,

  - reed canary grass (Bates, pers. comm.), when this is not the only bank material in the reach (Caldwell, pers. comm.),

  - non-native boulders originating from riprap,

- split channels with a noticeable difference in water surface elevation between the channels (Caldwell, pers. comm.), or

- gravel beds that do not extend entirely across the stream. In particular, no transect should be placed where the stream is deepest at the toe of a cut bank (Bates, pers. comm.).

• If less than four suitable reaches exist in the study segment, four transects should be measured on one or more of the qualifying reaches.

• If more than one transect is to be in a reach, the transects should be spaced as evenly as possible from one another.

• Additional reaches or more transects may be measured, until an additional transect does not greatly change the average toe width, or the investigator is intuitively satisfied that the present-day natural stream condition has been fairly represented (Beecher, pers. comm.).

Step Four: Define Toe of Bank

• The toe shall be designated only for that bank having the lowest toe (Swift 1979).

• The toe shall be the lowest of three points:

(1) The greatest change in slope between bank and bed, as determined either by visual inspection (Tom Higgins, U.S. Geological Survey (USGS), pers. comm.) or by a streambed elevation profile measured at regular intervals across the transect (USGS unpub. notes);

(2) The transition between perennial terrestrial vegetation and aquatic vegetation (Swift 1979); or

(3) The most definite change in texture between typical streambed material and typical bank soil (Beecher, pers. comm.).

• If the above criteria define more than one toe, the toe having the lowest elevation shall be chosen for stream width measurement. In particular, avoid using a higher toe if it is only submerged during infrequent periods of high water.

Step Five: Measure Stream Width

• Extend a tape measure parallel to the water surface along the transect line.

• Determine the vertical difference between the toe and the tape, or, if the toe is submerged, between the toe and the water surface, probing the streambed with a yardstick.

- Record the point on the tape directly above the toe.

- Moving toward the opposite bank, record that point on the tape where the ground rises to become equal to the toe elevation relative to the tape, or, if the toe is submerged, relative to the water surface.

Data Analysis

Toe width for each stream was averaged giving equal weight to each reach, as recommended by Beecher (pers. comm.). The mean toe width for each segment was entered into each of the five equations presented by Swift (1976, 1979) to estimate, respectively, the discharge required for:

Maximum chinook, pink, and chum spawning area,
Maximum coho spawning area,
Preferred salmon rearing area,
Maximum steelhead spawning area, and
Preferred steelhead rearing area;

using the formula:

$$Q = aTW^b,$$

Where:
Q = recommended flow (cfs)
a = correlation constant
TW = toe width (ft), and
b = correlation coefficient.

Parameters of the model were given by Swift (1979, 1976) for salmon and steelhead, respectively:

	Salmon			Steelhead	
	Spawning				
	Chinook, pink, chum	Coho	Rearing	Spawning	Rearing
a	1.360	0.550	0.139	1.550	0.164
b	1.240	1.310	1.440	1.160	1.420
Standard error of estimate	40%	48%	57%	28%	56%

Flow recommendations were calculated from this list for each month by selecting, from the species known to spawn or rear in the particular month (Table 5), that species and life stage with the highest calculated flow requirement.

RESULTS AND DISCUSSION

Toe width for 15 streams amenable to the Toe Width method and measured in 1993 ranged from 3.3 ft to 16.6 ft (Table 6), with many streams between 4 and 8 ft wide. Maximum spawning flow for chum or steelhead ranged from 6 to 44 cfs; preferred rearing flow ranged between approximately 1 and 9 cfs (Table 7). Monthly flow recommendations ranged from approximately 1 cfs for salmon rearing in Stream 17.0200 to 40 cfs for steelhead spawning in Leland Creek (Table 8). These recommendations imply that water use at all points in the stream system within and upstream of the study segment as shown in Table 4 must be managed to ensure adequate flow throughout the segment.

Actual Flows versus Recommended Flows

Considering streams for which actual flows have been routinely measured, the actual flows tended to be less than the recommended flows on most streams (Tables 9,10). Comparison of recommended flows to hydrologic records suggests that, in many study streams, further water appropriation would reduce fish habitat except during high flow events. However, some streams appeared more sensitive than others to further withdrawal, based on the number of months during which observed flows were likely to be less than recommended flows.

Streams with Monthly Flow Averages

- Spawning flow. On streams for which monthly flow estimates were available, the mean monthly flow was usually less than the recommended spawning flow, especially on Snow Creek (Table 9). The exceptions were the Little Quilcene River and the West Fork Chimacum Creek, where the mean monthly flow for some winter months was greater than the recommended spawning flow.

- Rearing flow. For streams with monthly flow data, the mean monthly flow tended to approximate the preferred rearing flow in spring and early summer but usually was less than the preferred rearing flow by late summer, the exception being the West Fork Chimacum.

Streams with Minimum and Maximum Flows of Record

- Spawning flow. For streams where only the minimum and maximum flows of record were available (Table 10), the maximum flow tended to be less than the recommended spawning flow, the exceptions being Cassalery and Meadowbrook Creeks. The wide discrepancy at Cassalery Creek is probably due to the very narrow low water channel for which toe width was measured; higher toes -- although their width was not measured -- were more obvious here than on any other stream I measured.

- Rearing flow. For these less extensively measured streams, the least sensitive to reduction in rearing flow were some of the streams whose flow was supplemented by diversion from the Dungeness River. Recorded minimum flows were greater than the preferred rearing flows in Cassalery and Meadowbrook Creeks and about the same on Bell Creek. Minimum flow of record was definitely below the recommended rearing flow on other streams.

The tendency of recommended flows to exceed measured flows is consistent with previous applications of the Toe Width Method to streams within the size range measured in the present study (Beecher and Caldwell, pers. comms.). However, my recommended flows may be lower, in relation to observed flows, than recommendations of other investigators for their respective streams. This is because wherever multiple toes occurred (Table 6), I consistently resolved the ambiguity of the published toe definition (Swift 1976,1979) in favor of the lowest toe elevation (see "Methods" section, above). These restrictions of the definition and use of the toe width method appeared "reasonable and appropriate in view of the general small size of most of the streams to which the method was applied" (Charles H.Swift III, pers. comm.) This choice led to the shortest alternative toe width measurement, and, therefore, to the lowest recommended flow that is biologically justifiable.

Influence of Irrigation Tailwater

For the small independent streams of the Dungeness Valley, it is impossible to discern the channel-shaping influence of natural watershed flow versus human alteration of the channel. The formerly natural channels of Meadowbrook, Cassalery, Gierin, Bell, and Johnson Creeks have been partially reshaped by (1) diverting irrigation water into these streams from the Dungeness River, (2) relocating, straightening, and dredging the channel (Johnson, pers. comm.), and (3) allowing reed canary grass to encroach on the banks. Our flow recommendations, which are based on combined water sources and altered channel shape, cannot accurately tell what "fish flows" an entirely natural channel would require. Nor can our recommendations tell us whether irrigation tailwater has increased the fish-carrying capacity of the streams. To the degree that human activity has reshaped these channels, it has masked the natural instream flow requirement. In these streams, the hydrologic base flow outside the irrigation season may suggest the streams' natural biological needs better than toe width measurements.

Reliability of Toe Width Method

All streams in this report except Ludlow Creek have flows determined from beyond the range of the defined parameters, leaving the matter of accuracy somewhat in question. This was because the toe width of 14 of the 15 streams in this study was less than 11 ft. In contrast, the toe width of streams used in the statistical analysis that produced the models ranged from 11 to 537 ft (Swift 1979). As a consequence, the method discounts the effect of woody debris and live trees as hydrologic controls, even though such features largely determine the streambed profile and the quantity of spawning habitat in the small streams typical of the study area.

Despite this difficulty, the present toe width measurements met the critical assumption of the rearing flow models; that is, that toe width corresponds to the discharge at which salmon and steelhead rearing habitat reaches a point of diminishing returns in relation to further flow increases. This was so because the measured toe widths appeared approximately equal to the presumed low flow width of the wetted channel.

Limits to Applicability of Toe Width Method

Instream flows could not be specified for Chevy Chase Creek (Stream 17.0215), Chimacum Creek (East Fork), Eagle Creek, East Squamish Creek (Stream 17.0183), and Streams 17.0016, 17.0276, 17.0277, and 17.0284 because of intermittent flow or lack of suitable measurement areas. No biological method of recommending instream flows for such streams appears to exist at present.

The Toe Width Method requires the investigator to choose segments representing the natural condition of the stream, even though all study area streams have received impacts which range from minor to catastrophic. Thus, flow recommendations apply only to existing hydrologic and hydraulic conditions, and may differ if habitat is brought closer to its pristine condition.

RECOMMENDATIONS

(1) Offstream water consumption and land use should be managed to maintain instream flows at the levels recommended in Tables 1 and 8 of this report.

(2) On streams whose flow comes partially from agricultural diversion from the Dungeness River, flows recommended in this study should be maintained until recommendations based on hydrologic base flow are established.

(3) On streams where the Toe Width Method or the Instream Flow Incremental Method could not be used, existing flows should be maintained until instream flow recommendations based on biological criteria are developed.

(4) The Toe Width Method should be refined to more accurately represent fish habitat area on small streams. Specifically, the method should account for the value of woody debris and other non-alluvial features that affect the shape and size of the channel.

BIBLIOGRAPHY

Beecher, H.A. 1980a. Wildlife and instream flows of the Quilcene Basin (WRIA 17). Habitat Management Division, Washington Department of Game, Olympia, Washington.

Beecher, H.A. 1980b. Fish, wildlife, and instream flows in the Elwha-Dungeness Basin (WRIA 18). Habitat Management Division, Washington Department of Game, Olympia, Washington.

Drost, B.W. 1986. Water resources of Clallam County, Washington: Phase 1 report. Water Resources Investigations Report 83-4227, U.S. Geological Survey, Tacoma, Washington,

Dungeness-Quilcene Regional Planning Group. 1993. Water Resource Pilot Planning Project Scoping Document. Jamestown S'Klallam Tribe, Sequim, Washington.

Hiss. J.M. 1993. Recommended instream flows for the lower Dungeness River. U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, Washington

Hiss, J.M. and P.L. Wampler. 1991. Fish habitat analysis for the Dungeness River using the Instream Flow Incremental Methodology. U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, Washington.

Swift, C.H. 1976. Estimation of stream discharges preferred by steelhead trout for spawning and rearing in western Washington. U.S. Geological Survey, Tacoma, Washington , Open-file report 75-155.

Swift, C.H. 1979. Preferred stream discharges for salmon spawning and rearing in Washington. Open-File Rept. 77-422, U.S. Geological Survey, Tacoma, Washington.

U.S. Department of Agriculture. 1991 Wetlands map: Dungeness watershed. Puget Sound Cooperative River Basin Team, Olympia, Washington.

Washington Departments of Fisheries, Ecology, and Game. 1987. Instream resources protection study report. Appendix II *In* Washington Department of Ecology. Washington's water resources program: instream resources and water allocation program review -- draft environmental impact statement. Washington Department of Ecology, Water Resources Program, Olympia, Washington.

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Treaty Indian Tribes. 1993. 1992 Washington state salmon and steelhead stock inventory. Washington Department of Fisheries, Washington Department of Wildlife, and Northwest Indian Fisheries Commission, Olympia, Washington.

Williams, R.W., R.M. Laramie, and J.J. Ames. 1975. A catalog of Washington streams and salmon utilization: Vol. I: Puget Sound region. Washington Department of Fisheries, Olympia, Washington.

Williams, J.R., H.E. Pearson, and J.D. Wilson. 1985. Streamflow statistics and drainage-area characteristics for the Puget Sound region, Washington -- Vol. I: western and southern Puget Sound. Open-File Report 84-144-A, U.S. Department of the Interior, Geological Survey, Tacoma, Washington.

Table 1. Review of previous instream flow recommendations for study area streams based on toe width measurements.

Stream	Species	Life stage	Period	Recommended flow (cfs)	Source
Big Quilcene River	Steelhead	Spawning	Feb-Jun	165	Beecher 1980a
	Steelhead	Rearing	Jul-Aug	50	Beecher 1980a
Chimacum Creek Mainstem	Steelhead	Spawning	Feb-Jun	50	Beecher 1980a
	Steelhead	Rearing	Jul-Aug	12	Beecher 1980a
Donovan Creek	Steelhead	Spawning	Feb-Jun	30	Beecher 1980a
	Steelhead	Rearing	Jul-Aug	7	Beecher 1980a
Jimmycomelately Cr.	Steelhead	Spawning	Feb-Jun	30	Beecher 1980b
	Steelhead	Rearing	Jul-Aug	6	Beecher 1980b
Little Quilcene R.	Steelhead	Spawning	Feb-Jun	75	Beecher 1980a
	Steelhead	Rearing	Jul-Oct	20	Beecher 1980a
McDonald Creek	Chum	Spawning	Nov-Dec	41	WDF unpub.
	Steelhead	Spawning	Feb-Jun	35	Beecher 1980b
	Steelhead	Rearing	Jul-Oct	8	Beecher 1980b
Salmon Creek	Steelhead	Spawning	Feb-May	40	Beecher 1980a
	Steelhead	Rearing	Jun-Aug	9	Beecher 1980a
Siebert Creek	Chum	Spawning	Nov-Dec	60	WDF unpub.
	Coho	Spawning	Jan	28	WDF unpub.
	Steelhead	Spawning	Feb-Jun	50	Beecher 1980b
	Steelhead	Rearing	Jul-Oct	12	Beecher 1980b
Snow Creek	Steelhead	Spawning	Feb-May	63	Beecher 1980a
	Steelhead	Rearing	Jun-Aug	8	Beecher 1980a
Tarboo Creek	Steelhead	Spawning	Dec-Jun	40	Beecher 1980a
	Steelhead	Rearing	Jul-Nov	8	Beecher 1980a
Thorndyke Creek	Steelhead	Spawning	Nov-Jan	45	Beecher 1980a
	Steelhead	Rearing	Feb-Oct	10	Beecher 1980a

Table 2. Watersheds with and without flow recommendations as of April, 1993 in the Project Area.

Status	County	Stream	Watershed area (sq mi)
Flows recommended	Jefferson	Big Quilcene River	68.1
		Chimacum Creek mainstem	33.6
		Donovan Creek	
		Little Quilcene River	35.0
		Salmon Creek	18.8
		Snow Creek	23.1
		Tarboo Creek mainstem	12.4
		Thorndyke Creek	12.1
		Total	203.1
	Clallam	Dungeness River[B]	198.0
		Jimmycomelately Creek	15.4
		McDonald Creek	23.0
		Siebert Creek	19.5
		Total	255.9
No flows recommended	Jefferson	Chevy Chase Creek (Stream 17.0215)	[A]
		Chimacum Creek East Fork	6.8
		Chimacum Creek West Fork	13.8
		Contractors Creek	2.6
		Eagle Creek	5.4
		East Squamish Creek (Stream 17.0183)	[A]
		Howe Creek	5.5
		Leland Creek	11.3
		Ludlow Creek	[A]
		Ripley Creek	[A]
		Shine Creek (Stream 17.0181)	5.2
		Stream 17.0116	[A]
		Stream 17.0200	[A]
		Tarboo Creek East Fork	[A]
		Total	50.6+
	Clallam	Bell Creek	8.9
		Cassalery Creek	3.2
		Chicken Coop Creek (Stream 17.0278)	[A]
		Gierin Creek	3.1
		Johnson Creek	4.7
		Meadowbrook Creek	0.5
		Stream 17.0276	[A]
		Stream 17.0277	[A]
		Stream 17.0284	[A]
		Total	20.4+

[A] Not available from Stream Catalog (Williams *et al.* 1975).

[B] Recommended by Instream Flow Incremental Method; all other flows recommended by Toe Width Method.

Table 3. Suitability of study area streams for toe width measurement.

Stream	River Mile	Road	Flowing?	Measurable?	Accessible?
Bell Cr.	0.1	Schmuck Rd.	Yes	Yes	Yes
	1.0	Rhodefer Rd.	No	No	Yes
	1.3	Blake Rd.	Yes	No[A]	Yes
Casssalery Cr.	0.0	Jamestown Rd.	?	?	No
	0.6	Jamestown Rd.	Yes	No[B]	Yes
	1.1	Taylor Ranch Rd.	Yes	No[B]	Yes
	1.2	Dungeness Rd.	Yes	No[B]	Yes
	1.6	Woodcock Rd.	Yes	Yes	Yes
Chicken Coop Cr. (Stream 17.0278)	0.1	E. Sequim Bay Rd.	Yes	Yes	Yes
Chevy Chase Cr. (Stream17.0215)	0.2	Cape George Rd.	No	No	Yes
Chimacum Creek (East Fork)	0.2	Center Rd.	Yes	No[C]	Yes
	1.0	E. Chimacum Valley Rd.	Yes	No[C]	Yes
	7.0	Center Rd.	Yes	No[C]	Yes
Chimacum Cr. (West Fork)	3.4	West Chimacum Valley Rd.	Yes	No[C]	Yes
	8.9	Eaglemount Rd.	Yes	Yes	Yes
Contractors Cr.	0.2	Old Gardiner Rd.	Yes	Yes	Yes
Eagle Cr.	0.1	Daisy King Rd.	?	?	No
	0.6	Farnsworth Rd.	No	No[D]	Yes
	0.7	Rd. 128	Yes	No[D]	Yes
	0.8	Gardiner-Clallam	No	No	Yes
	1.2	Diamond Point Rd.	No	No	Yes
	1.7	Highway 101	Yes	No[A]	Yes
	2.1	Chicken Coop Rd.	?	?	No
	2.6	Klinke Rd.	Yes	No[E]	Yes
East Squamish Cr. (Stream 17.0183)	0.1	Shine Rd.	Yes	No[B]	Yes
Gierin Cr.	1.6	Holland Rd.	Yes	No[F]	Yes
	2.5	Brown Rd.	Yes	Yes	Yes
Howe Creek	0.0	Lords Lake Loop	Yes	Yes	Yes
Johnson Cr.	0.1	E. Sequim Bay Rd.	Yes	Yes	Yes
	0.0	Marina	Yes	No[A]	Yes

Table 3, continued.

Stream	River Mile	Road	Flowing?	Measurable?	Accessible?
Leland Creek	1.0	Hwy. 101	Yes	Yes	Yes
Ludlow Creek	0.2	Paradise Bay Rd.	Yes	Yes	Yes
Meadowbrook Cr.	0.6	Palmer St.	Yes	No	Yes
	0.9	Dungeness Rd.	Yes	No	Yes
	1.0	Dungeness Rd.	Yes	Yes	Yes
	1.5	School Rd.	Yes	No	Yes
Ripley Creek	0.2	Lords Lake Loop	Yes	Yes	Yes
Shine Creek (Stream 17.0181)	0.9	Hwy. 104	Yes	Yes	Yes
Stream 17.0016	0.0	E. Quilcene Rd.	?	?[G]	No
Stream 17.0200	0.2	Oak Bay Rd.	Yes	Yes	Yes
Stream 17.0276	0.4	Deer Ct.	No	No	Yes
Stream 17.0277	0.1	E. Sequim Bay Rd.	No	No	?
Stream 17.0284	0.2	Old Gardiner Rd.	Yes	No[C]	Yes
Tarboo Creek (East Fork)	4.5	Center Rd.	Yes	Yes	Yes

A Stream artificially straightened.
B No pools or potential spawning riffles observed.
C No potential spawning riffles observed.
D Peat bottom; not alluvial material.
E Wetted perimeter less than 1 ft; stream considered too small for measurement.
F All riffles controlled by woody debris.
G Intermittent.

Table 4. Stream segments represented by 1993 study reaches, based on approximate similarity of gradient and location of tributaries.

Stream	Study reach (river mi)	Segment boundaries Lower river mi	Upper river mi	Segment length (mi)	Gradient (percent)
Bell Cr.	0.2	0.0	1.1	1.1	1.4
Cassalery Cr.	1.6	1.3	1.6	0.3	0.8
Chicken Coop Cr. (Stream 17.0278)	0.1	0.0	1.8	1.8	1.9
Chimacum Cr. (West Fork)	8.9	8.2	11.1	2.9	0.9
Contractors Cr.	0.3	0.1	2.8	2.7	2.5
Gierin Cr.	2.6	1.5	2.7	1.2	1.3
Howe Cr.	0.6	0.5	1.8	1.3	1.5
Johnson Cr.	0.2	0.0	1.5	1.5	2.5
Leland Cr.	0.0	0.0	0.5	0.5	2.5
Ludlow Cr.	0.2	0.1	0.2	0.1	7.6[A]
Meadowbrook Cr.	0.9	0.9	1.4	0.5	0.2
Ripley Cr.	0.2	0.0	1.5	1.5	1.3
Shine Cr. (Stream 17.0181)	0.8	0.5	2.0	1.5	1.3
Stream 17.0200	0.2	0.1	0.8	0.7	5.1
Tarboo Cr. (East Fork)	4.6	4.3	6.0	1.7	3.8

[A] Map contour includes falls; stream segment lies between falls and tidewater. Gradient of segment is lower than that indicated by map contours, and is suitable for spawning.

Table 5. Occurrence and spawning season of salmon and steelhead in Dungeness-Quilcene Project Area streams. Source: WDF *et al.* 1993 except where noted.

Stream	Species	Stock	Spawn timing
Bell Creek	Coho	Dungeness	Oct-Jan[A]
Big Quilcene River	Summer Chum	Hood Canal	Sep-Oct
	Late fall chum	Quilcene	Nov-Jan
	Winter steelhead	Quilcene-Dabob	Feb-Jun
Cassalery Creek	Coho	Dungeness	Oct-Jan[A]
Chicken Coop Cr. (Stream 17.0278)	Coho?	Sequim Bay	Oct-Jan[A]
Chimacum Creek	Coho	Chimacum Creek	Nov-Jan
	Fall chum	West Hood Canal	Nov-Jan[B]
	Winter steelhead	Not specified	Feb-Jun[B]
Contractors Cr.	Coho	Discovery Bay	Oct-Feb[C]
	Winter steelhead	Discovery Bay	Feb-May[C]
Donovan Creek	Coho	Quilcene-Dabob	Nov-Jan[B]
	Fall chum	West Hood Canal	Nov-Jan[B]
Dungeness River	Spring-summer chinook	Dungeness	Aug-Oct[D]
	Pink	Upper Dungeness	Aug-Sep[D]
		Lower Dungeness	Sep-Oct[D]
	Coho	Dungeness	Oct-Jan[D]
	Fall chum	East Strait	Nov-Dec[D]
	Summer steelhead	Dungeness	Feb-Apr[D]
	Winter steelhead	Dungeness	Feb-Jun[D]
East Squamish Cr. (Stream 17.0183)	Coho	Quilcene-Dabob	Nov-Jan[B]
Gierin Creek	Coho	Dungeness	Oct-Jan[A]
	Winter steelhead	Sequim Bay	Feb-Jun
Howe Creek	Coho	Quilcene-Dabob	Nov-Jan[B]
Jimmycomelately Cr.	Coho	Sequim Bay	Oct-Jan
	Summer chum	Sequim Bay	Sep-Oct
	Winter steelhead	Sequim Bay	Feb-Jun
Johnson Creek	Coho	Sequim Bay	Oct-Jan[A]
	Chum	Not specified	Sep-Dec[A,E]
	Winter steelhead	Sequim Bay	Feb-Jun
Leland Creek	Coho	Quilcene-Dabob	Nov-Jan[B]
	Winter steelhead	Quilcene-Dabob	Feb-Jun[B]

Table 5 continued.

Stream	Species	Stock	Spawn timing
Little Quilcene R.	Coho	Quilcene-Dabob	Nov-Jan[B]
	Late fall chum	Quilcene	Nov-Jan
	Winter steelhead	Quilcene-Dabob	Feb-Jun
Ludlow Creek	Coho	Quilcene-Dabob	Nov-Jan[B]
	Fall chum	West Hood Canal	Nov-Jan[B]
	Winter steelhead	Quilcene-Dabob	Feb-Jun[B]
McDonald Creek	Coho	Morse Creek	Nov-Jan
	Fall chum	East Strait	Nov-Dec
	Winter steelhead	Morse Creek	Feb-Jun
Meadowbrook Creek	Coho	Dungeness	Oct-Jan[A]
Ripley Creek	Coho	Quilcene-Dabob	Nov-Jan[B]
Salmon Creek	Coho	Discovery Bay	Oct-Feb
	Summer chum	Discovery Bay	Sep-Oct
	Winter steelhead	Discovery Bay	Feb-May
Shine Cr. (Stream 17.0181)	Coho	Quilcene-Dabob	Nov-Jan[B]
	Fall chum	West Hood Canal	Nov-Jan[B]
Siebert Creek	Coho	Morse Creek	Nov-Jan
	Fall chum	East Strait	Nov-Dec
	Winter steelhead	Morse Creek	Feb-Jun
Snow Creek	Coho	Discovery Bay	Oct-Feb
	Summer chum	Discovery Bay	Sep-Oct
	Winter steelhead	Discovery Bay	Feb-May
Stream 17.0200	Coho	Quilcene-Dabob	Nov-Jan[B]
	Fall chum	West Hood Canal	Nov-Jan[B]
Tarboo Creek	Coho	Quilcene-Dabob	Nov-Jan[B]
	Fall chum	West Hood Canal	Nov-Jan[B]
	Winter steelhead	Quilcene-Dabob	Feb-Jun
Thorndyke Creek	Coho	Quilcene-Dabob	Nov-Jan[B]
	Fall chum	West Hood Canal	Nov-Jan[B]

same

[A] Mike Reed, Jamestown S'Klallam Tribe, pers. comm.
[B] Peter Bahls, Port Gamble S'Klallam Tribe and Carol Bernthal, Point-no-Point Treaty Council, pers. comms.
[C] Inferred from fish occurrence in Snow and Salmon Creeks.
[D] Source: Hiss (1993).
[E] Not determined whether stream supports early run, normal-timed run, or both.

Table 6. Toe width data (in ft) collected by FWS in May and June of 1993. See Table 4 for description of study segments.

Stream	Reach	Date	Transect	Toe type[A] Lowest	Toe type[A] Higher	Constraints[A] Bank[B]	Constraints[A] Bed	Toe width
Bell Cr. (Figure 1)	1	0526	A	C	--	C2	--	9.2
			B	C	--	C2	--	11.9
			C	C	--	C2	--	8.8
			D	C	--	C2	--	9.7
			Mean					9.9
	2	0526	A	C	--	C,T	--	6.7
			B	C	--	C,T	--	6.5
			C	C	--	C2	--	7.1
			D	C	--	C2	--	5.9
			Mean					6.6
	Mean							8.2
Cassalery Cr. (Figure 2)	1	0526	A	G,S	V	E	--	4.0
			B	G,S	V	E	--	2.5
			C	G,S	V	E	--	2.6
			D	G,S	V	E	--	3.7
			Mean					3.2
	2	0526	A	G,S	--	E	--	6.0
			B	G,S	--	E	--	5.7
			C	G,S	--	E	--	5.5
			D	G,S	--	E	--	5.5
			Mean					5.7
	Mean							4.4
Chicken Coop Cr. (Stream 17.0278)	1	0526	A	G	--	--	--	10.2
			B	G	--	--	--	10.2
			C	G	--	--	--	9.3
			D	G	--	--	--	8.6
			Mean					9.6
	2	0526	A	G	--	--	--	7.0
			B	G	--	--	--	6.2
			C	U	--	--	--	6.0
			D	G	--	--	--	6.0
			Mean					6.3
	Mean							7.9

Table 6, continued.

Stream	Reach	Date	Transect	Toe type[A] Lowest	Toe type[A] Higher	Constraints[A] Bank[B]	Constraints[A] Bed	Toe width
Chimacum Cr.	1	0610	--	C	--	C1	--	3.8
(West Fork)	2	0610	--	U	--	C1	--	5.4
(Figure 3)	3	0610	--	G,V	V	V	--	11.0
	4	0610	--	U	--	T1	W	10.3
	5	0610	--	G	U,V	T,C	--	11.8
	6	0610	--	G	G	T,V	--	6.0
	Mean							8.0
Contractors Cr.	1	0528	A	G,S	--	--	--	5.5
(Figure 4)			B	G,S	--	--	--	4.7
			C	G,S	--	--	--	4.5
			D	G,S	--	--	--	4.9
		0602	E	U	--	--	--	3.9
			Mean					4.7
	2	0528	A	U	G,S	--	--	3.7
			B	G	--	--	--	4.7
			C	G	--	--	--	4.5
		0602	D	V	--	--	--	6.0
			Mean					4.7
	Mean							4.3
Gierin Cr.	1	0526	A	S,V	--	V1	--	9.0
(Figure 5)			B	S,V	--	--	--	9.3
			C	S,V	--	--	--	9.5
			D	S,V	--	--	--	10.1
			Mean					9.5
	2	0526	A	S,V	--	--	--	8.2
			B	S,V	--	--	--	7.6
			C	S,V	--	--	--	8.3
			D	S,V	--	--	--	7.1
			Mean					7.8
	Mean							8.6
Howe Cr.	1	0602	A	V	--	--	--	9.9
			B	V	--	--	--	8.9
			C	V	--	--	--	8.1
			D	V	--	--	--	8.1
			Mean					8.8

Table 6, continued.

Stream	Reach	Date	Transect	Toe type[A] Lowest	Toe type[A] Higher	Constraints[A] Bank[B]	Constraints[A] Bed	Toe width
Johnson Cr. (Figure 6)	1	0602	A	G,S	--	R1	--	10.7
			B	G,S	--	R1	--	2.6
			C	G,S	--	R1	--	2.6
			D	G,S	--	R1	--	2.0
			Mean					4.5
	2	0602	--	G	--	R1	--	4.3
	3	0602	--	G	--	--	--	5.7
	Mean							4.8
Leland Cr.	1	0602	A	S	--	--	--	11.6
			B	S	--	--	--	11.8
			C	S	--	--	--	12.2
			D	S	--	--	--	13.1
			Mean					12.2
	2	0602	--	G	--	--	S	18.8
	3	0602	A	G	--	--	--	20.8
			B	G	--	--	--	21.2
			C	G	--	--	--	21.5
			D	G	--	--	--	18.6
			Mean					20.5
	4	0602	A	G	G	--	--	21.7
			B	G	G	--	B	10.4
			C	G	G,S	--	--	17.8
			D	G	G	--	--	9.0
			Mean					14.7
	Mean							16.6
Ludlow Cr.	1	0611	A	G,S	--	--	--	1.1
			B	G	--	--	--	8.0
			C	G	--	--	--	15.0
			D	G,S	--	--	--	8.6
			Mean					8.2
	2	0611	--	G	G	--	--	7.5
	3	0611	--	G	G,S	--	--	9.6
	4	0611	--	G	G,S	V1	W	4.2
	Mean							7.4

Table 6, continued.

Stream	Reach	Date	Transect	Toe type[A] Lowest	Toe type[A] Higher	Constraints[A] Bank[B]	Constraints[A] Bed	Toe width
Meadowbrook Cr. (Figure 7)	1	0528	A	V	--	T,V	--	6.9
			B	V	--	T,V	--	6.0
			C	V	--	T,V	--	7.1
			D	V	--	T,V	--	8.0
			Mean					7.0
	2	0528	A	G	C	T,V	--	5.9
			B	G	C	T,V	V	7.9
			Mean					6.9
	Mean							7.0
Ripley Cr.	1	0602	A	U	--	--	--	5.4
			B	G	G	--	--	4.8
			C	S	G,V	--	--	3.4
			D	S	V	--	S	6.8
			Mean					5.1
	2	0602	A	S	--	--	--	3.6
			B	V	--	--	--	2.7
			C	U	--	--	--	2.9
			D	G	V	--	--	2.8
			Mean					3.0
	3	0602	--	G	--	W1	--	5.2
	Mean							4.4
Shine Cr. (Stream 17.0181) (Figure 8)	1	0603	A	G,S	--	--	B	11.2
		0611	B	U	V,G	T,W	W,B	8.7
			Mean					10.0
	2	0603	A	G	--	--	W	0.8
			B	G	U	T1	W	3.5
			C	G	--	--	W	2.5
			D	U	--	T1	W	6.2
			Mean					3.3
	Mean							6.6
Stream 17.0200	1	0611	--	G,S	--	--	--	4.4
	2	0611	A	G	S	--	--	4.1
			B	G	S	--	--	4.6
			Mean					4.4
	3	0611	A	G,S	--	--	--	4.2
			B	G	G	--	--	1.8
			Mean					3.0
	4	0611	--	G	U	--	--	2.5
	5	0611	--	S	--	W1	--	2.3
	Mean							3.3

Table 6, continued.

Stream	Reach	Date	Transect	Toe type[A] Lowest	Toe type[A] Higher	Constraints[A] Bank[B]	Constraints[A] Bed	Toe width
Tarboo Cr. East Fork	1	0611	A	G,S	--	--	--	3.5
			B	G,S	--	--	--	1.1
			C	G	--	--	--	3.6
			D	G,S	G,S	--	--	4.0
			Mean					3.1
	2	0611	A	G	--	--	--	5.4
			B	G	--	--	--	4.2
			C	G	--	--	--	5.7
			D	G	--	--	--	6.0
			Mean					5.3
	3	0611	--	G,S	--	--	--	3.5
	Mean							4.0

[A] B = Boulders from culvert riprap mildly affecting transect profile.
C = Canary grass (forms much more solid barrier to erosion than other vegetation).
E = Embankment near road, possibly constricting channel.
G = Toe determined based on geometry of alluvial streambed; toe located at angle of transition from bed to bank.
R = Rushes or other annual riparian vegetation form relatively weak resistance to stream flow.
S = Substrate texture change from coarse gravel to pea gravel, sand, or mud.
T = Living tree trunks or roots near or below water surface.
U = Undercut bank.
V = Vegetation other than pure stand of canary grass or rushes.
W = Large woody debris in stream bottom or bank.

[B] "1" or "2" following letter indicates whether one or both banks are constrained.

Table 7. Calculation of spawning and rearing flows (cfs) from 1993 toe width measurements conducted by FWS and cooperators.

Stream	Toe width (ft)	Water-shed area (sq mi)	Salmon[A] Spawning Chinook, chum	Salmon[A] Spawning Coho	Salmon[A] Rearing	Steelhead[B] Spawning	Steelhead[B] Rearing
Bell Cr.	8.2	8.9	18.5	8.7	2.9	17.9	3.3
Cassalery Cr.	4.4	3.2	8.6	3.9	1.2	8.7	1.4
Chicken Coop Cr. (Stream 17.0284)	7.9	[C]	17.7	8.3	2.7	17.1	3.1
Chimacum Cr. (West Fork)	8.0	13.8	18.1	8.5	2.8	17.4	3.2
Contractors Cr.	4.3	2.6	8.3	3.7	1.1	8.4	1.3
Gierin Cr.	8.6	3.1	19.7	9.3	3.1	18.9	3.5
Howe Cr.	8.8	5.5	20.0	9.4	3.2	19.2	3.6
Johnson Cr.	4.8	4.7	9.6	4.3	1.3	9.6	1.5
Leland Cr.	16.6	11.3	44.2	21.7	7.9	40.2	8.8
Ludlow Cr.	7.4	[C]	16.2	7.5	2.5	15.7	2.8
Meadowbrook Cr.	7.0	0.5	15.1	7.0	2.3	14.7	2.6
Ripley Cr.	4.4	[C]	8.6	3.9	1.2	8.7	1.4
Shine Cr. (Stream 17.0181)	6.6	5.2	14.1	6.5	2.1	13.8	2.4
Stream 17.0200	3.3	[C]	6.0	2.6	0.8	6.2	0.9
Tarboo Cr. (East Fork)	4.0	[C]	7.5	3.3	1.0	7.6	1.2

[A] Model parameters from Swift (1979).
[B] Model parameters from Swift (1976).
[C] Not available.

Table 8. Flow recommendations by month for streams measured by FWS in 1993.

Stream	Species	Life stage	Period	Recommended flow (cfs)
Bell Creek	Coho Salmon	Spawning	Oct-Jan	8.7
		Rearing	Feb-Sep	2.9
Cassalery Creek	Coho Salmon	Spawning	Oct-Jan	3.9
		Rearing	Feb-Sep	1.2
Chicken Coop Creek	Coho Salmon	Spawning[A]	Oct-Jan	8.3
		Rearing	Feb-Sep	2.7
Chimacum Creek (West Fork)	Steelhead	Spawning	Feb-Jun	17.4
	Steelhead	Rearing	Jul-Oct	3.2
Contractors Creek	Coho	Spawning	Oct-Feb	3.7
	Steelhead	Spawning	Feb-May	8.4
	Steelhead	Rearing	Jun-Sep	1.3
Gierin Creek	Coho	Spawning	Oct-Jan	9.3
	Steelhead	Spawning	Feb-Jun	18.9
	Steelhead	Rearing	Jul-Sep	3.5
Howe Creek	Coho Salmon	Spawning	Nov-Jan	9.4
		Rearing	Feb-Oct	3.2
Johnson Creek	Coho	Spawning	Oct	4.3
	Chum	Spawning	Nov-Jan[B]	9.6
	Steelhead	Spawning	Feb-Jun	9.6
	Steelhead	Rearing	Jul-Aug	1.5
Leland Creek	Coho	Spawning	Nov-Jan	21.7
	Steelhead	Spawning	Feb-Jun	40.2
	Steelhead	Rearing	Jul-Oct	8.8
Ludlow Creek	Chum	Spawning	Nov-Jan	16.2
	Steelhead	Spawning	Feb-Jun	15.7
	Steelhead	Rearing	Jul-Oct	2.8
Stream 17.0200	Fall chum Salmon	Spawning	Nov-Jan	6.0
		Rearing	Feb-Oct	0.8
Meadowbrook Creek	Coho Salmon	Spawning	Oct-Jan	7.0
		Rearing	Feb-Sep	2.3
Ripley Creek	Coho Salmon	Spawning	Nov-Jan	4.4
		Rearing	Feb-Oct	1.4
Stream 17.0181 (Shine Creek)	Chum[C] Salmon	Spawning	Nov-Jan	14.1
		Rearing	Feb-Oct	2.1
Tarboo Creek (East Fork)	Coho	Spawning	Nov-Jan	3.3
	Steelhead	Spawning	Feb-Jun	7.6
	Steelhead	Rearing	Jul-Oct	1.2

[A] Occurrence uncertain.
[B] Spawn timing uncertain.
[C] Other species may occur and thus increase total spawning season.

Table 9. Mean monthly flow for period of record, and recommended monthly flows in study area streams. Streams not having recorded flows do not appear in this table. Number of years of record appear in parentheses under stream name. Shaded areas indicate months when recommended flow is less than monthly mean.

Stream	Type flow	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Chimacum Cr. (West Fork) (7)	Mean[A]	6	11	26	36	33	26	15	8	8	5	4	4
	Rec.[B]	3				17	17	17	17	17	3	3	3
Jimmycome-lately Cr. (1)	Mean[C]										2.2	1.7	1.6
	Rec.[D]					30	30	30	30	30	6	6	
Little Quilcene R. (10)	Mean[A]	22	59	71	88	85	62	66	60	58	36	20	15
	Rec.[E]	20				75	75	75	75	75	20	20	20
Siebert Cr. (18)	Mean[F]	7	20	27	44	40	22	15	11	8	5	4	4
	Rec.[D]	12	60	60	28	50	50	50	50	50	12	12	12
Snow Cr. (22)	Mean[F]	6	12	24	32	27	24	22	19	13	8	4	4
	Rec.[E]					63	63	63	63	8	8	8	

[A] Mean monthly flow for period of record, averaged from annual data in Williams *et al.* (1985).
[B] Recommended in present study.
[C] Mean monthly flow for period of record, presented by Drost (1986).
[D] Recommended by Beecher (1980a).
[E] Recommended by Beecher (1980b) and WDF (unpub.)
[F] Mean monthly flow for period of record, presented by Williams *et al.* (1985).

Table 10. Maximum and minimum daily flow for period of record, and recommended monthly flows in study area streams. Streams not having recorded flows do not appear in this table. Number of years of record appear in parentheses under stream name. Shaded areas indicate months when recommended flow is less than minimum of record.

Stream	Type flow	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
Bell Cr. (5)	Max.[A]													9.2
	Min.[A]													3.08
	Rec.[B]	9	9	9	9	3	3	3	3	3	3	3	3	
Cassalery Cr. (4)	Max.[A]													16.5
	Min.[A]													3.71
	Rec.[B]	4	4	4	4	1	1	1	1	1	1	1	1	
Gierin Cr. (4)	Max.[A]													13.4
	Min.[A]													2.45
	Rec.[B]	9	9	9	9	19	19	19	19	19	4	4	4	
Jimmycome-lately Cr. (1)	Max.[A]													12.5
	Min.[A]													1.1
	Rec.[C]					30	30	30	30	30	6	6		
Johnson Cr. (2)	Max.[A]													6.9
	Min.[A]													0.24
	Rec.[B]	4	10	10	10	10	10	10	10	10	10	2	2	
McDonald Cr. (2)	Max.[A]													27.6
	Min.[A]													0.61
	Rec.[D]	8	41	41	35	35	35	35	35	35	8	8	8	
Meadow-brook Cr. (5)	Max.[A]													7.1
	Min.[A]													3.99
	Rec.[B]	7	7	7	7	2	2	2	2	2	2	2	2	

[A] Maximum daily flow and minimum daily flow for period of record, presented by Drost (1986). Jimmycomelately Creek appears in both Tables 9 and 10 because mean flow was not available for all months.
[B] Recommended in present study.
[C] Recommended by Beecher (1980a).
[D] Recommended by Beecher (1980b) and WDF (unpub.).

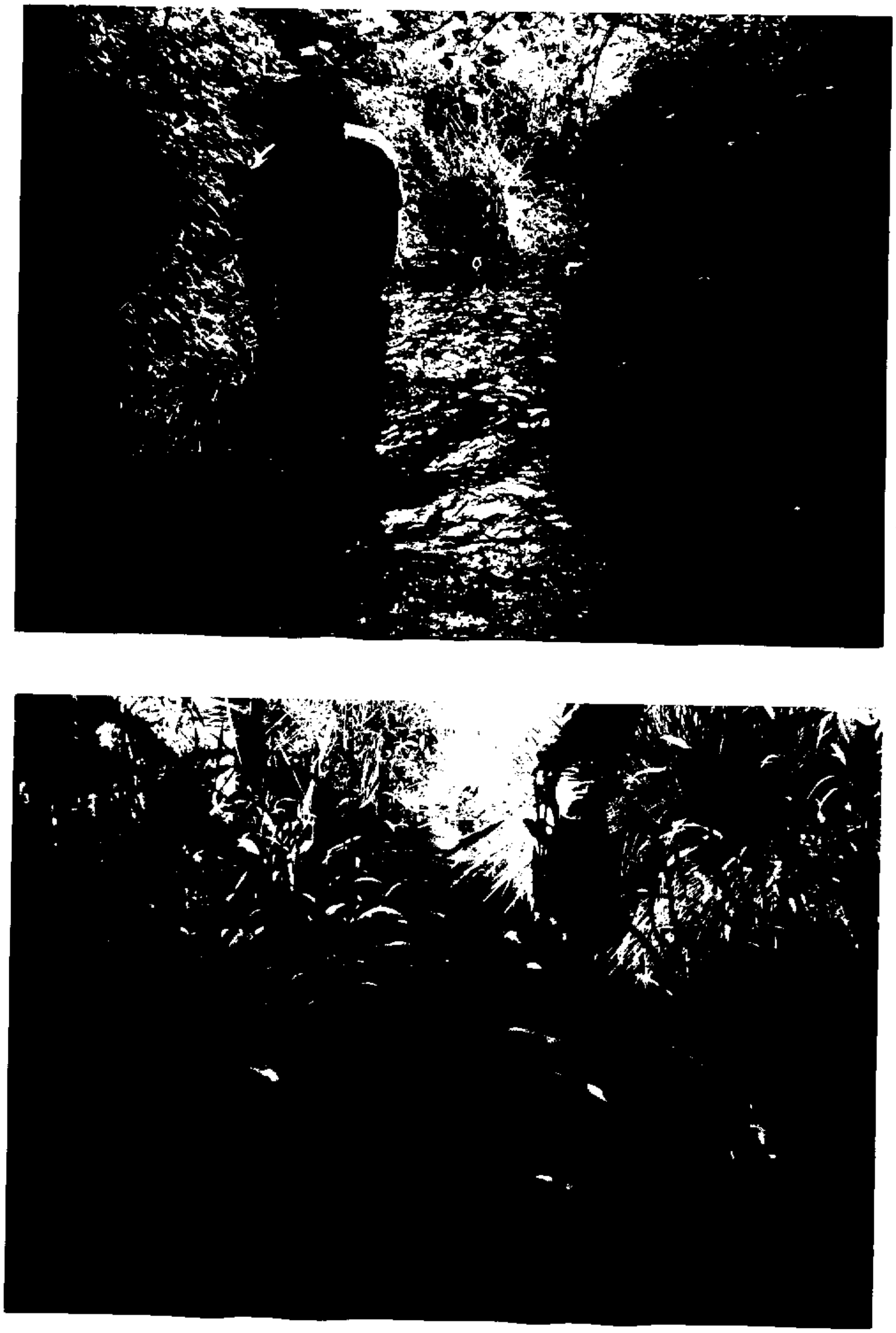


Figure 1. Bell Creek below Schmuck Road. **Above:** Lower reach, showing typical thickness of reed canary grass defining the bank, overhanging berry vines making measurement difficult, and poorly-defined pools due to relatively high flow. **Below:** Upper reach, showing extent of reed canary grass onto both sides of channel.

Figure 2. Cassalery Creek along Woodcock Road. **Above:** Lower reach, showing partially-submerged terrestrial vegetation on banks and in channel, and extent of mud bar on left bank (stake). **Below:** Upper reach, showing edge of low-water channel (between feet of two persons), partial armoring of bank with small woody debris (left), and watercress bed (right).

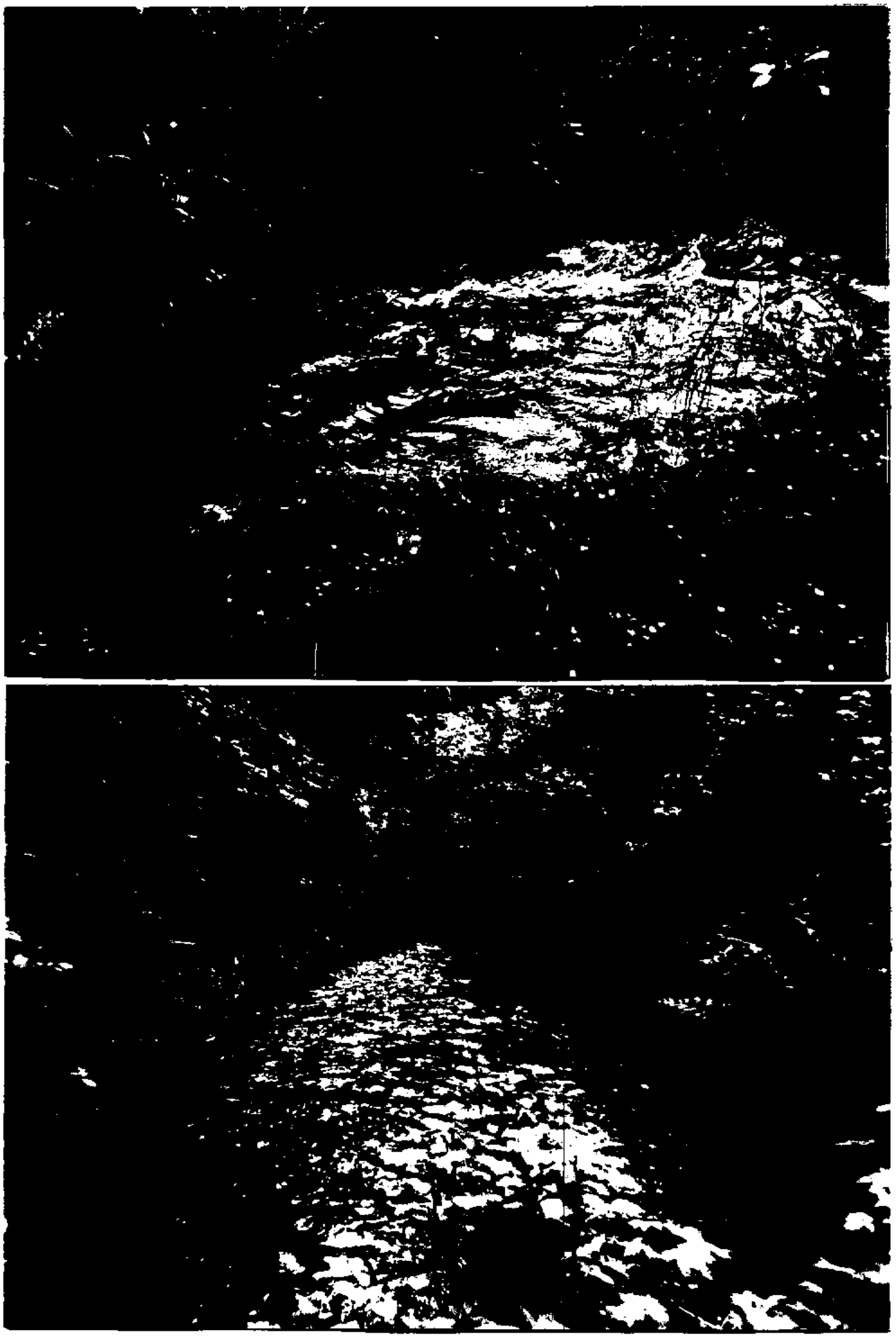


Figure 3. Chimacum Creek, west fork, downstream of Eaglemount Road. **Above:** Reach 1, showing small area of gravel exposed on near bank and slight constriction due to bank sloughing on far bank. **Below:** Reach 3, showing turbulence over top of riffles typical of this flow level, extent of overhanging vegetation, and relatively slight encroachment of canary grass. **Above (next page):** Reach 4, showing break in slope of bottom with accompanying change in gravel size (lower end of reflection of measuring stick), transition from stream bottom to soil at water's edge, undercut (behind measuring stick), and edge of terrestrial vegetation on top of overhang. **Below (next page):** Reach 4, showing slight influence of large woody debris on right, and uppermost transect location (measuring stick) relative to riffle downstream.

Figure 4. Contractors Creek upstream of Old Gardiner Road. Lower reach, showing transect location (stake), clay toe and vegetation line on left.

Figure 5. Gierin Creek at Brown Road. Grazing may have removed enough grass to allow the stream to naturally shape the channel, but trampling by cattle has obscured the transition from streambed to bank, so that the toe of the bank had to be defined as a slight change in slope along the transects.

Figure 6. Johnson Creek upstream of East Sequim Bay Road. **Above:** Reach 1 showing typical turbulence over area that would become the lower end of a pool in lower flow; and toe of left bank at water's edge on left. Lower toe existed on right bank about 0.5 ft below water, as defined by change in slope and texture of bottom. **Below:** Reach 4, showing typical turbulence over area that would become the lower end of a pool in lower flow; and partial constriction of channel due to scouring-rushes on both banks.

Figure 7. Meadowbrook Creek downstream of Dungeness Road at firehouse. **Above:** Reach 1, showing low gradient over gravelly areas; banks stabilized by rows of alder, buttercup, and canary grass. **Below:** Reach 2, showing edge of canary grass (stake) and indistinct toe composed of soft mud between stake and hard root mass of grass (at upper side of boot).

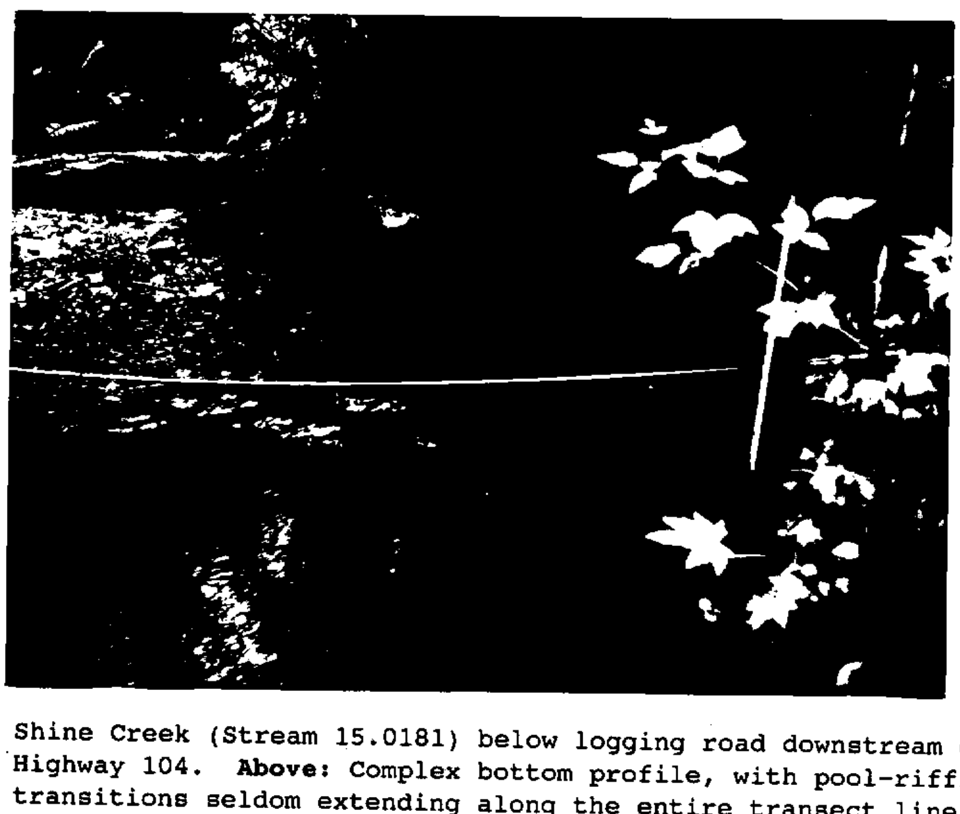


Figure 8. Shine Creek (Stream 15.0181) below logging road downstream of Highway 104. **Above:** Complex bottom profile, with pool-riffle transitions seldom extending along the entire transect line. **Below:** Large embedded woody debris weakly affecting channel width; and typical deep undercut along almost the entire right bank along the riffle.